AN EXPERIMENTAL RESEARCH PROGRAMME ON HETEROGENEOUS COMBUSTION PROCESSES UNDER MICROGRAVITY CONDITIONS. PRELIMINARY RESULTS

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Abstract

In the present work preliminary results are given of an experimental programme on flame spreading over the surface of PMMA rods in N_2-O_2 mixtures under microgravity conditions.

Results were obtained in the NASA KC-135 aircraft laboratory. Six experiments were carried out in March of this year and 36 more experiments will be conducted in March 1987.

These preliminary experiments allowed to determine the flame spreading velocities for three different mixture compositions. showing that they were smaller but of the same order of magnitude than downwards spreading velocities at one g and for the same mixture conditions.

Background

It is well known that gravity exerts a strong influence on many combustion processes specially those in which the flame is of the diffusion type. These types of flames take place when a flame spreads along the surface of a condensed fuel (solid or liquid) within a gaseous oxidizing atmosphere.

A rapidly grown interest is being shown on combustion processes under microgravity conditions, with the result that an important number of research programmes are or have been in progress, such as those listed in Refs. 1 through 8.

Flame spreading processes are of special interest since they would be the predominant spreading mechanism of fires in spacecrafts or space laboratories.

In addition, no results were available on this combustion process under microgravity conditions, and this was the reason for the selection of these experiments to be conducted in parabolic aircraft flights, with a view to further research programmes in rockets or in space laboratories.

Preliminary experimental programme on the ground

A research programme on flame spreading processes along the surface of condensed fuels is being carried out at the Escuela Técnica Superior de Ingenieros Aeronáuticos of the Universidad Politécnica de Madrid, which is being sponsored by the Microgravity Department of the European Space Organization.

The programme is both theoretical and experimental, and at this respect cylindrical symmetry has been selected since it permits a better theoretical modeling of the process.

Until now the experimental programme has been carried out with PMMA cylinders in nitrogen-oxygen mixtures.

A first part of the programme has been conducted on the ground at low pressure in order to reduce the Grashof number and in a free fall chamber test facility at the Instituto Nacional de Técnica Aeroespacial. The objectives of these experiments were, in the first place, to obtain order of magnitudes of ignition times, flame spreading velocities and minimum sizes of the combustion chambers in order to design the experiments for the parabolic aircraft flights. In addition, results of flame spreading velocities as function of pressure and mixture composition were obtained at one g, to be later compared with the results obtained in flight under microgravity conditions.

In Figures 1, 2 and 3 some of these results are shown and in Figures 4 and 5 photographs of the flame spreading process at ambient and at low pressure are shown.

Flight programme

A series of flame spreading experiments are programmed to be conducted in the NASA KC-135 aircraft laboratory with PMMA rods and other fuels.

Until now only six experiments were carried out in March of this year, and 36 experiments will be carried in March 1987. Therefore, only preliminary results are available.

Due to the short time available to prepare the experiments and also due to safety regulations, the ignition system utilized on the ground, based on a solid propellant was not feasible to be utilized, and a provisional system based on a hot wire was used, which produced some distortion of the flame at the end of the rod.

Three combustion chambers of 25 dm^3 of volume were prepared (Figures 6 and 7) and six tests were carried out with rods of 70 mm in length and 5 mm in diameter . Spreading velocities were measured from the photographs utilizing a densimeter, and due to irregularities results from only three experiments are considered reliable and are shown in Figures 1, 2 and 3, where they are compared with results obtained at one g. In Figure 8 a sequence of the flame spreading process is shown.

Conclusions

1) The flame spreads. This conclusion is important, since there existed some doubts that flames might not spread in this type of systems under microgravity conditions.

2) Flame spreading velocities were smaller than downward flame spreading velocities at one g but of the same order of magnitude.

3) Flames were irregular in shape, probably due to the nature of the fuel and not to aircraft induced vibrations, since they also existed in the free-fall chamber experiments, as shown in Figure 9.

References

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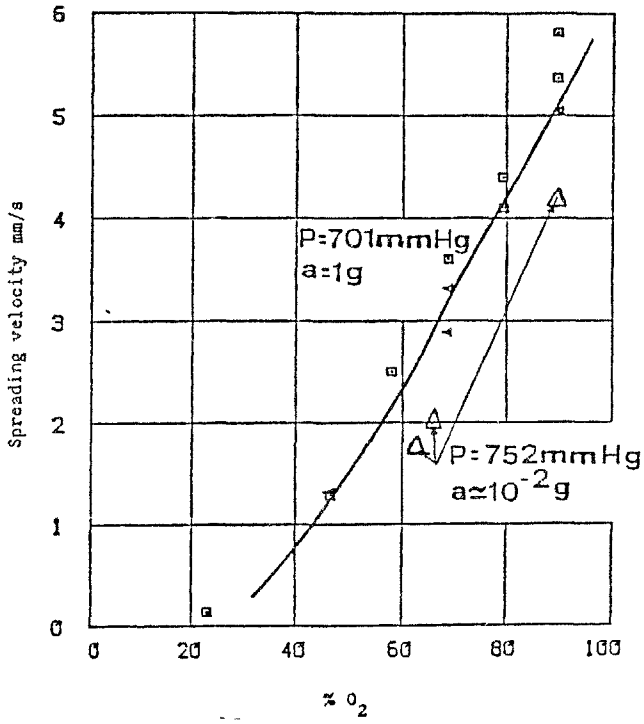


Figure 1.- Downward steady spreading velocity as function of O_2 concentration.

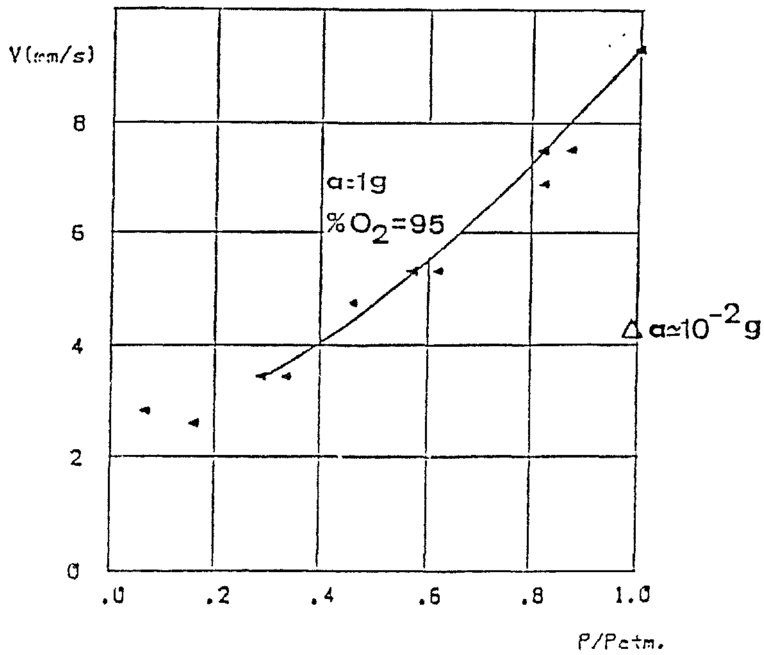


Figure 2.- Downward steady spreading velocity as function of pressure.

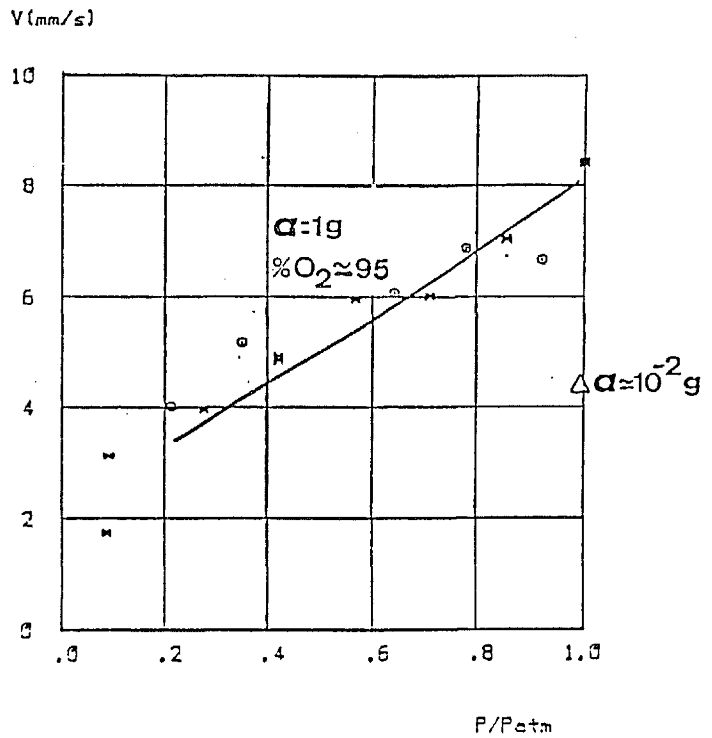


Figure 3.- Horizontal steady spreading velocity as function of pressure.

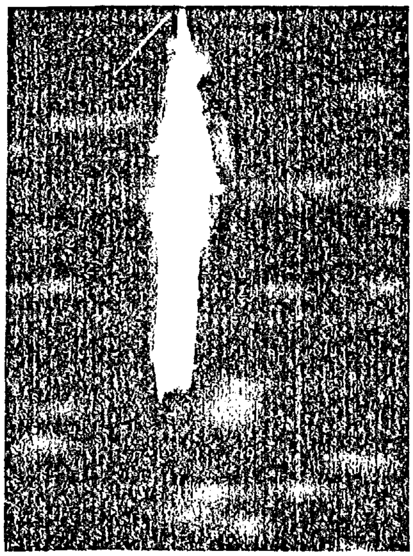


Figure 4.- Downward spread of flames along PMMA cylinders. O_2=95%, P=760 mm Hg.

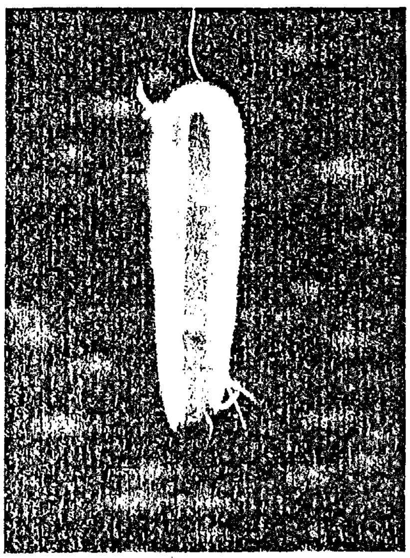


Figure 5.- Downward spread of flames along PMMA cylinders. O_2-95%, P=47 mm Hg

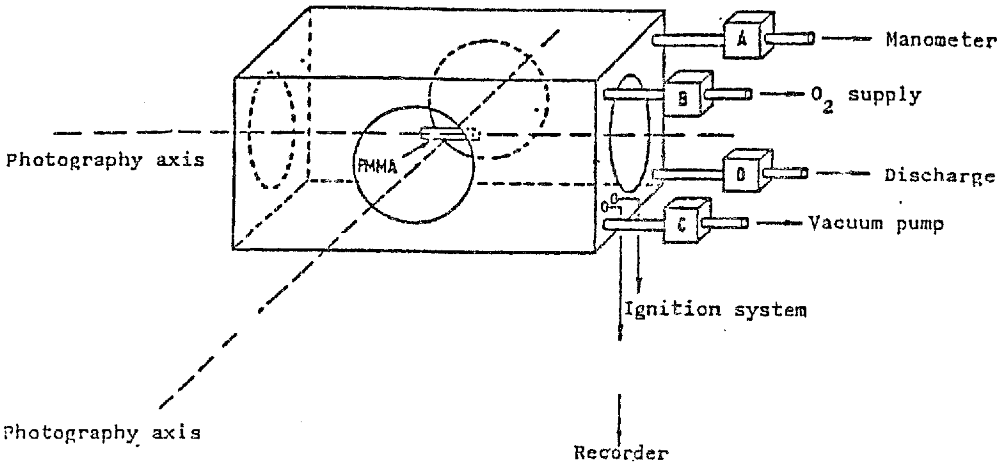


Figure 6.- Schematic diagram of combustion chamber.

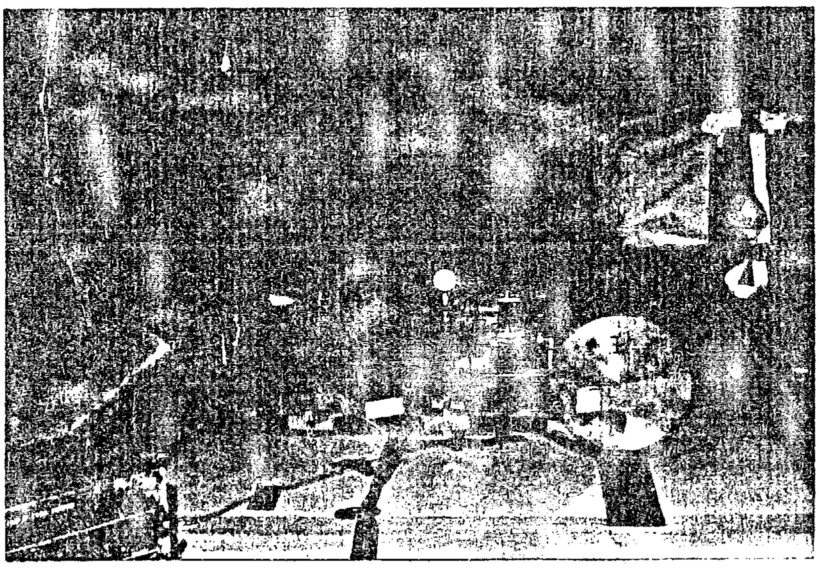
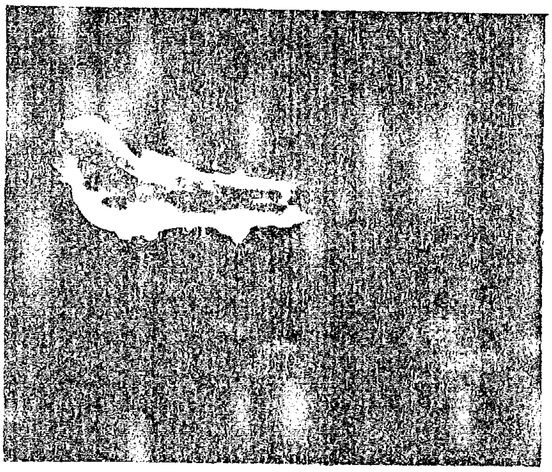
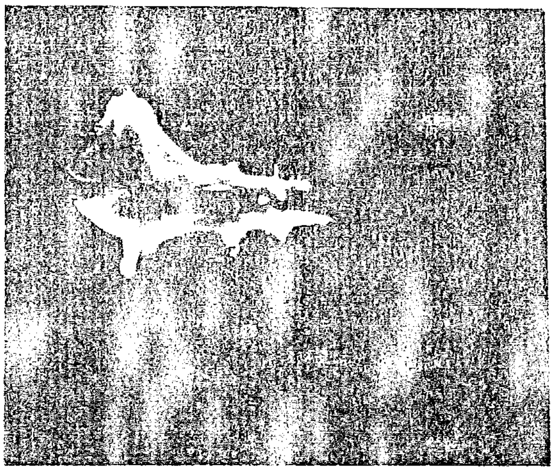


Figure 7.- Experimental installation in flight.

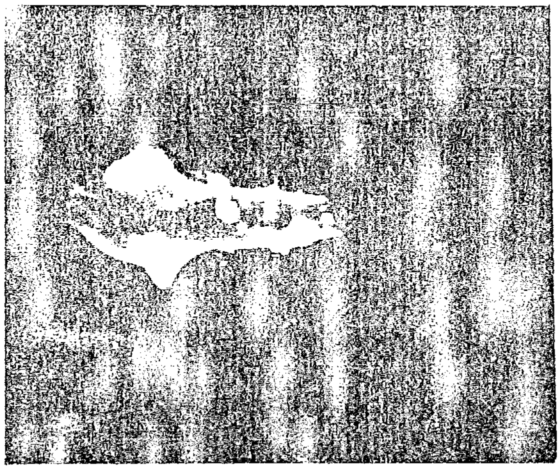


t = 0 s.

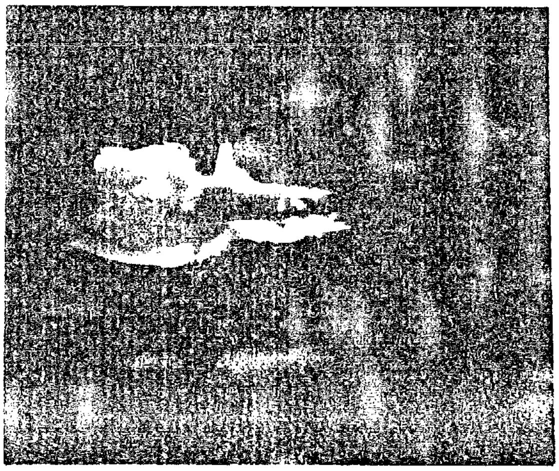
t = 0.4 s.



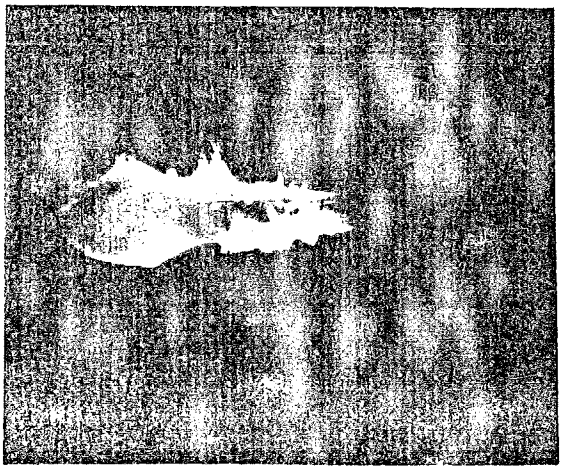
t = 0.8 s



t = 1.2 s.



t = 1.6 s.

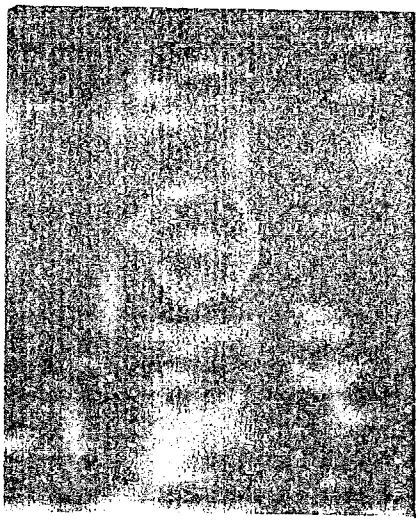


t = 2 s.

Figure 8.- A serie of six consecutive photographs for horizontal spread of flame along PMMA cylinders under microgravity conditions (KC-135 aircraft laboratory) P = 752 mm Hg and O_2 = 67%.

t = 0.111 s.

t = 0.277 s.



t = 0.777 s.

t = 0.944 s.

Figure 9.- A sequence of PMMA flame in a free-fall test chamber.